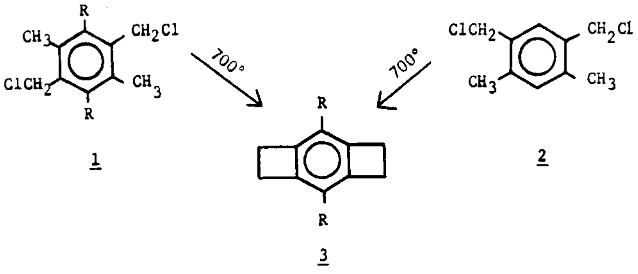
Communications to the Editor

Syntheses of Benzo[1,2:4,5]dicyclobutene Derivatives

Sir:

Recently there has been a renaissance of interest in methods of preparing benzocyclobutenes,[1] in their employment as intermediates in syntheses of natural products and molecules of novel structure,[2] and in both their physical properties and those of their valence tautomers, the *o*-xylylenes.[3] We now report a convenient method for the synthesis of benzo[1,2:4,5]dicyclobutene derivatives and the use of one of these derivatives, 3,6-dimethylbenzo[1,2:4,5]dicyclobutene (**3b**), as an intermediate in the synthesis of a novel cyclophane, [2.2](3,6)-benzo[1,2:4,5]dicyclobutenophane (**4**).

When either of the α,α'-dichlorodurenes, **1a** or **2**,[4a,b] is introduced by sublimation at 0.04-0.10-mm pressure into the hot zone (700 °C) of a jacketed quartz tube, collection of the pyrolysis product at −30 °C gives after purification, either by steam distillation or trituration with methanol followed by recrystallization from aqueous methanol, pure benzo[1,2:4,5]dicyclobutene (**3a**) in 30% yield. The yield is about the same starting with either **1a** or **2**, but the pyrolysis of **2** is cleaner and the purification of **3a** in this case is easier. Similarly, **1b**[5] and **1c**[6] are converted to **3b** and **3c**, respectively, and in about the same yield. The physical properties of these products are summarized in Table I.



a, R = -H; b, R = -CH$_3$; c, R = -Br

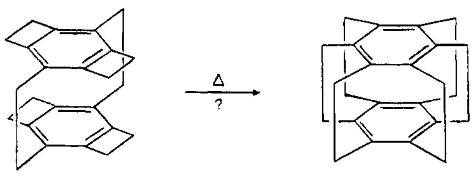
Studies on the electrophilic aromatic substitution of benzocyclobutene have shown that a complex mixture of products results, including ring-opened products, presumably resulting from ipso attack.[9] In the chemical studies of benzo[1,2:4,5]dicyclobutene (**3a**) thus far completed, we have found that electrophilic aromatic substitution occurs exclusively by ipso attack giving the corresponding ring-opened products in high yield. For example, chloromethylation of **3a**, using paraformaldehyde and anhydrous hydrogen chloride in acetic acid, gave, after workup and purification by chromatography, 4-chloromethyl-5-(2′-chloroethyl)benzocyclobutene in 85% yield as a colorless oil: ^{1}H NMR τ 2.90 (s, 1 H, ArH), 3.05 (s, 1 H, ArH), 5.30 (s, 2 H, -CH$_2$Cl), 6.80 (s, 4 H, -C*H*$_2$C*H*$_2$-), and 6.1-6.9 (m, 4 H, ArC*H*$_2$C*H*$_2$Cl); *m/e* 214.

In view of the known thermal dimerization of benzocyclobutenes to dibenzocyclooctadienes,[10] it was of interest to extend our syntheses of benzo[1,2:4,5]dicyclobutenes to the preparation of layered cyclophanes incorporating juxtaposed benzocyclobutene moieties which could undergo this type of thermal bond reorganization to give multiply bridged cyclophanes. Of particular interest was the cyclophane **4**, which might isomerize to give [2.2.2.2.2.2](1,2,3,4,5,6)cyclophane (**5**), a hypothetical molecule representing an extreme example of face-to-face crowding of two benzene rings.[11]

Table I. Physical Properties of the Benzo[1,2:4,5]dicyclobutenes

Compd	Mp, °C	^{1}H NMR, τ (CDCl$_3$)	Mass spectra[a] (peaks of high relative intensity), *m/e* (70 eV)
3a[b]	100-101	3.20 (2 H), 6.88 (8 H)	130, 115
3b	119-120	7.96 (6 H), 7.00 (8 H)	158, 143, 128
3c	128-130	7.00 (8 H)	288, 244, 208

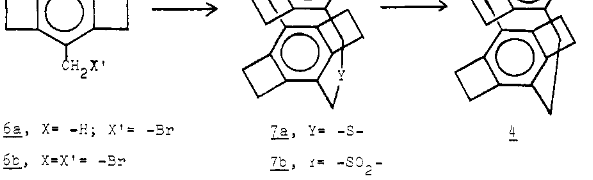
[a] Reference 8. [b] Reference 7.



4 5

The synthesis of **4** was accomplished following the usual dithiacyclophane methods developed previously.[12] Treatment of **3b** with *N*-bromosuccinimide led to two products: **6a**, in 10% yield after recrystallization from 2-propanol, as white prisms; mp 51-60 °C; NMR τ 5.68 (s, 2 H, -CH$_2$Br), 6.97 (s, 8 H, -CH$_2$-), 7.98 (s, 3 H, -CH$_3$); *m/e* 238, 236, 157, 141, 128, 115; **6b**, in 10% yield after recrystallization from an ethyl acetate-hexane mixture, as white crystals; mp 159-161 °C; NMR τ 5.71 (s, 4 H, -CH$_2$Br), 6.90 (s, 8 H, -CH$_2$-); *m/e* 318. Reaction of **6b** with potassium thioacetate in dimethylformamide was complete in 2 h and, after workup and recrystallization of the product, gave **6c** in 98% yield as white needles: mp 179 °C dec; NMR τ 6.36 (s, 4 H, -CH$_2$S-), 7.25 (s, 8 H, -CH$_2$-), 7.96 (s, 6 H, -CH$_3$). Lithium aluminum hydride reduction of **6c** in tetrahydrofuran gave **6d**, in 99% yield after recrystallization from 2-propanol, as white plates: mp 87-92°; NMR τ 6.45 (d, 4 H, J = 7.5 Hz, -CH$_2$S-), 6.81 (s, 8 H, -CH$_2$-), 8.35 (t, 2 H, J = 7.5 Hz, -SH); *m/e* 222. The coupling of **6b** and **6d** was carried out in the usual way[13] and gave **7a**, after recrystallization from chloroform, in 41% yield as white prisms: mp 310 °C dec; NMR τ 6.37 (s, 8 H, -CH$_2$-), 6.68 and 7.15 (d, 16 H, J = 10 Hz, -C*H*$_2$CH$_2$-); *m/e* 376. Oxidation of **7a** in chloroform with *m*-chloroperbenzoic acid gave the bissulfone **7b** in 100% yield, after recrystallization from hexafluoroacetone hydrate, as white prisms: mp 335 °C dec; NMR τ 5.61 (s, 8 H, -C*H*$_2$SO$_2$-), 6.40 and 6.98 (d, 16 H, J = 12 Hz, -C*H*$_2$CH$_2$-); *m/e* 440.

Subjection of **7b** to the normal pyrolysis conditions for expelling sulfur dioxide from sulfones[14] led only to the formation on the cold finger of an unusual cellophane-like polymer. Photolysis, following the procedure of Rebafka and Staab,[15]



6a, X= -H; X'= -Br
6b, X=X'= -Br
6c, X=X'= -SAc
6d, X=X'= -SH

7a, Y= -S-
7b, Y= -SO$_2$-

4

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left **7b** unchanged. However, irradiation of a solution of **7b** in hexafluoracetone hydrate using a medium-pressure Hanovia lamp led, on concentration of the solution, to the separation of **4** in 30% yield as white crystals: mp 320 °C dec; NMR τ 7.65 (s, 8 H), 6.44 and 7.07 (d, 16 H, J = 11 Hz); *m/e* 312, 284, 156.

Cyclophane **4** is of interest both as a first example of a cyclophane having a fused cyclobuteno moiety and as an example of a completely substituted [2.2]paracyclophane.[16] Longone and Simanyi have previously synthesized 4,5,7,8,12,13,15,16-octamethyl[2.2]paracyclophane and reported that the molecule was not very stable, significant losses occurring owing to polymerization during isolation and even on storage at 0 °C in the solid state.[17] Cyclophane **6** is appreciably more stable and can be sublimed unchanged at 190 °C and 10^{-5} mm. The pyrolysis of **4** is discussed in the accompanying communication.[18]

Acknowledgment. We thank the National Science Foundation for their support of this investigation.

References and Notes

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(5) Supplied by Aldrich Chemical Co.

(6) Prepared by chloromethylation of 2,6-dibromo-*p*-xylene using chloromethyl methyl ether in 30% fuming sulfuric acid. Obtained, after recrystallization from carbon tetrachloride, in 62% yield as colorless crystals: mp 183–185 °C; ^{1}H NMR ($CDCl_3$), a singlet at τ 5.12 (4 H, $-CH_2Cl$) and a singlet at 7.30 (6 H, $-CH_3$). The structure of this, as well as all other new compounds reported in this communication, is supported by satisfactory elemental analyses and.or high resolution mass spectra. Unless otherwise specified, NMR spectra were taken using deuteriochloroform as solvent.

(7) Benzo[1,2:4,5]dicyclobutene (**3a**) was first prepared by M. P. Cava, A. A. Deana, and K. Muth (*J. Am. Chem. Soc.*, **82**, 2524 (1960)), who report its melting point at 101 °C.

(8) The parent molecular ions of **3a, 3b,** and **3c** each show an envelope of peaks corresponding to loss of one, two, and three hydrogens. The peaks for **3c** at 288 and 244 show the typical isotope pattern for the presence of two bromine atoms.

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(16) During the course of this investigation Blickle and Hopf have been able to prepare a [2.2]paracyclophane having two fused cyclobuteno rings (private communication from Professor Henning Hopf).

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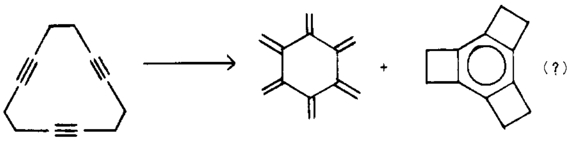
(18) See L. G. Harruff, M. Brown, and V. Boekelheide, *J. Am. Chem. Soc.* following paper in this issue.

Richard Gray, Lewis G. Harruff, John Krymowski
Jane Peterson, Virgil Boekelheide*
Department of Chemistry, University of Oregon
Eugene, Oregon 97403
Received November 28, 1977

Hexaradialene: Precursors and Structure

Sir:

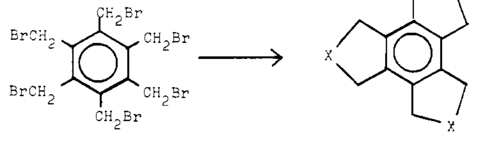
Barkovich, Strauss, and Vollhardt have discussed the theoretical interest in hexaradialene and have assigned the hexaradialene structure **2** to the $C_{12}H_{12}$ hydrocarbon obtained on pyrolysis of 1,5,9-cyclododecatriyne **1**.[1] Whether or not benzo[1,2:3,4:5,6]tricyclobutene **3** should be proposed as an intermediate in the conversion of **1** to **2** is not clear, although in an earlier communication,[2] in which the same authors described the synthesis of **1**, it was stated that the thermal reorganization of **1** most likely proceeds via intermediate **3**.



1 2 3

In a study of the thermal behavior of [2.2](3,6)benzo[1,2:4,5]dicyclobutene (**6**),[3] in which we had hoped to observe the formation of [2.2.2.2.2.2](1,2,3,4,5,6)cyclophane, we obtained instead a $C_{12}H_{12}$ hydrocarbon having identical spectral properties with that obtained by the Berkeley group from the pyrolysis of **1**. In particular, the mass spectral fragmentation pattern of this hydrocarbon is very characteristic, showing only a low intensity parent molecular ion at *m/e* 156 in an envelope of signals varying by one mass unit each from 157 to 151 and with additional peak envelopes at 141 and 128.[4] Although the chemical properties observed for the $C_{12}H_{12}$ hydrocarbon fit the hexaradialene structure **2**,[1] this behavior could likewise be rationalized in terms of structure **3**, and the mass spectral fragmentation pattern seems easier to interpret for structure **3** than for **2**. The single piece of evidence strongly favoring **2** over **3** was the proton spectrum which has a singlet at τ 4.69 (toluene-d_8). This chemical shift corresponds closely to the value (τ 4.7) reported for the vinyl protons of hexamethylhexaradialene,[5] and, although such a chemical shift would not be impossible for **3**, it would be quite unusual.

In an attempt to obtain an authentic sample of **3** for comparison, we have prepared the trissulfone **5b** and examined its pyrolysis. Treatment of hexa(bromomethyl)benzene[6] (**4**) with sodium sulfide using a phase transfer technique readily gave the trissulfide **5a** in 40% yield, after recrystallization from chloroform, as colorless crystals: mp 241–246 °C dec; NMR ($CDCl_3$), a singlet at τ 5.82; mass spectrum *m/e* 252.[7] Oxidation of the trissulfide **5a** with *m*-chloroperbenzoic acid in chloroform gave the trissulfone **5b** as colorless crystals: mp >350 °C dec; NMR ($(CF_3)_2C(OD)_2$), a singlet at τ 5.56.



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5a, X= -S-

5b, X= $-SO_2-$

Pyrolysis of **5b** at 900 °C, using the technique described previously,[1,8] gave the same $C_{12}H_{12}$ hydrocarbon as had been obtained from pyrolyses of **1** and of **6**. The mass spectral fragmentation pattern was reproduced in complete detail. With this result, we began examining other compounds on hand that might yield a $C_{12}H_{12}$ hydrocarbon on pyrolysis. Quickly, we found that the benzo[1,2:4,5]dicyclobutene derivatives **7** and **8**[7] both gave the same hydrocarbon and the same mass spectral fragmentation pattern. Ironically, the compound which gives

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